TABLE III

INFRARED SPECTRA OF METHYLPYRROLES

(600–1000-cm^{-1} region)

Compound	Absorption bands, cm^{-1} [a,b]				
Pyrrole		722 s	867 w		
N-Methylpyrrole	660 w	720 s		968 m	
2-Methylpyrrole	699 s	778 w			
3-Methylpyrrole	689 w	756 s			
2,3-Dimethylpyrrole	638 m	711 s	830 m	899 m	951 w
2,4-Dimethylpyrrole	645 m	729 m	787 s	956 w	983 w
2,5-Dimethylpyrrole	643 m	769 s			991 m
3,4-Dimethylpyrrole[c]		775 s	885 w		979 m
2,3,4-Trimethylpyrrole	651 m	731 s		959 w	982 w
2,3,5-Trimethylpyrrole	636 m	646 sh	782 s	951 w	
2,3,4,5-Tetramethylpyrrole[d]	650 s			946 w	

[a] Spectrum obtained on neat liquid unless otherwise stated. [b] Relative absorbance: w = weak, m = medium, s = strong. [c] Run on melted sample, neat. [d] Run in KBr disk.

tosylate. Since titration indicated that all of the Grignard had been consumed, the reaction was hydrolyzed after 1 hr using twice the volume of 0.1 *M* phosphoric acid. The reaction was worked up and analyzed as before. The methylation was repeated using one tenth the amount of methyl tosylate. Each methylation was run in duplicate.

B. **Other Alkylations.**—For the alkylations with ethyl bromide, *n*-propyl bromide, and isopropyl bromide, 0.2 mole of the appropriate alkyl bromide was added to 0.1 mole of the pyrrylmagnesium bromide solution. After allowing the resulting homogeneous solution to stand while protected from light for 48 hr, at the end of which time the reaction was at least 95% complete, the reaction was hydrolyzed and worked up as before. With *t*-butyl bromide only an equimolar amount of the halide was added and the reaction was hydrolyzed and worked up after 1 hr. The alkylations were repeated but allowed to go only about 10% by either hydrolyzing the reactions after only 0.5–2 hr, or in the case of *t*-butyl bromide, by adding only 10% of the halide.

Product Analysis.—Gas chromatography of the alkylpyrroles was carried out at 150° on the equipment and column previously described.[5] An F & M Model 810 instrument equipped with a 6-ft SE-30 column, and programmed at 10°/min from 50 to 250° was used for the separation of the pyrrolenines. Retention times (relative to pyrrole) for the synthetic methylpyrroles were N-methylpyrrole, 0.42; 2- and 3-methylpyrroles, 1.41; 2,5-dimethylpyrrole, 1.81; 2,4-dimethylpyrrole, 1.93; 2,3-dimethylpyrrole, 2.11; 3,4-dimethylpyrrole, 2.23; 2,3,5-trimethylpyrrole, 2.86; 2,3,4-trimethylpyrrole, 3.24; and 2,3,4,5-tetramethylpyrrole, 4.67. Quantitative analysis was carried out in quadruplicate by Disc® integration of peak areas. Except in the case of N-methylpyrrole, the areas were proportional to the mole fraction of the component. The ratio of 2- to 3-methylpyrrole and 2,3- to 2,5-dimethylpyrrole was determined by trapping the appropriate fractions in small condensers attached to the detector outlet. The condensed material was dissolved in isooctane and the infrared spectrum was determined in a 0.05-mm cavity cell using a beam condenser on a Beckman IR-8 instrument. The wavelengths used for the 2- and 3-methylpyrroles were 778 and 756 cm^{-1}, respectively,[1] and for the 2,3- and 2,5-dimethylpyrroles, 711 and 787 cm^{-1}. The results from four collections were averaged.

The relative retention times for the higher alkylpyrroles were 2-ethyl, 1.90; 3-ethyl, 2.18; 2,5-diethyl, 4.06; 2,3-diethyl, 5.29; 2,3,5-triethyl, 7.3; 2-*n*-propyl, 3.01; 3-*n*-propyl, 3.69; 2,5-di-*n*-propyl, 8.15; 2,3-di-*n*-propyl, 10.2; 2,3,5-tri-*n*-propyl, 19.0; 2-isopropyl, 2.12; 3-isopropyl, 2.93; 2,5-diisopropyl, 4.15; 2,3,5-triisopropyl, 5.73; 2-*t*-butyl, 2.16; 3-*t*-butyl, 3.34; 2,5-di-*t*-butyl, 6.30; 2,3,5-tri-*t*-butyl, 11.9.

Acknowledgment.—This work was supported by a grant from the Rutgers University Research Council. The author is indebted to Professor P. S. Skell for his valuable suggestions made during the course of this work. The assistance of Miss B. Lundy is gratefully acknowledged.

Reactions of the Perfluoroalkylnitriles. VIII. Syntheses of 1,3,5-Triazines with Specific Groups in the 2, 4, or 6 Positions[1,2]

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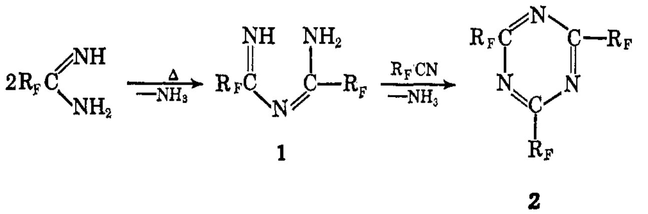
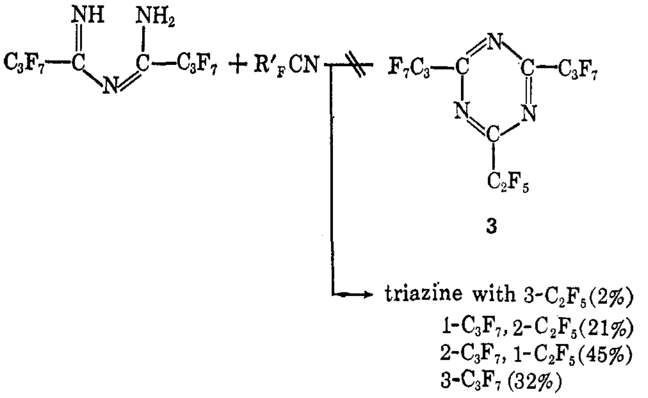
The initial step in the synthesis of 2,4,6-tris(perfluoroalkyl)-1,3,5-triazines by the deammonation of perfluoroalkylamidines was shown by Brown and Shuman[3] to be the formation of N′-(perfluoroacylimidoyl)perfluoroalkylamidine (**1**). This intermediate was found to undergo a further reaction with perfluoroalkyl nitriles, with the liberation of ammonia, to produce 2,4,6-tris(perfluoroalkyl)-1,3,5-triazines (**2**).



From these results, it would seem possible to produce a specific perfluoroalkyl-substituted triazine with any desired perfluoroalkyl groups in the 2, 4, or 6 positions, since in previous work, no difficulty had been found in producing N′-(perfluoroacylimidoyl)perfluoroalkylamidines with unlike perfluoroalkyl groups. For the purpose of determining the usefulness of this approach, a model reaction was set up using N′-(perfluorobutyrimidoyl)perfluorobutyramidine, and 1 molar equiv of perfluoropropionitrile. This procedure did not produce exclusively the triazine **3**, with two C_3F_7 and one C_2F_5 groups; all four possible C_3F_7- and C_2F_5-substituted triazines were found when the reaction product was examined by vapor phase partition chromatography. Reaction temperatures from 65 (123 hr) to 130° (2 hr) did not materially alter the percentages,



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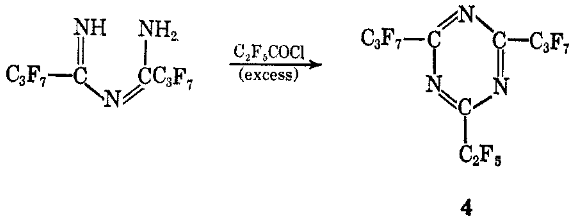
(1) (a) This research has supported by the Air Force Materials Laboratory, Research and Technology Division, Air Force Systems Command, U. S. Air Force under Contracts AF33(616)7971 and AF33(615)1368. (b) Preceding paper in this series by H. C. Brown and C. R. Wetzel, *J. Org. Chem.*, **30**, 3734 (1965).

(2) This paper taken in part from the dissertation presented by Paul D. Schuman to the Graduate School of the University of Florida in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

(3) H. C. Brown and P. D. Schuman, *J. Org. Chem.*, **28**, 112 (1963).

which were found to be those calculated for random distribution.[4] This close agreement is presumably due to the similarity in reactivity of the nitriles used. An additional experiment in which N′-(perfluoropropionyl)perfluorobutyramidine was allowed to stand at room temperature until 73% conversion to triazine had taken place showed the distribution of C_3F_7- and C_2F_5-substituted triazines that could be calculated for a 1.0:1.0 molar ratio of the two different R_F groups. A similarly random redistribution of R_F and R'_F groups was observed when a mixture of 2,4,6-tris(perfluoropropyl)-1,3,5-triazine and 2,4,6-tris(perfluoroethyl)-1,-3,5-triazine in a 2.0:1.0 molar ratio was heated at 100° in the presence of ammonia.

Since the reaction of N′-(perfluoroacylimidoyl)perfluoroalkylamidines with perfluoroalkylnitriles clearly would lead only to 2,4,6-perfluoroalkyl-substituted 1,3,5-triazines with random distribution of the substituents, another method of converting the imidoylamidines to triazines was sought. For this purpose, acylation of the amino group of the imidoylamidine was undertaken, and it was found that in the presence of an excess of acylating reagent, which served also as a dehydrating reagent, ring closure took place readily. The initial reactions of this type were carried out using perfluoropropionyl chloride and N′-(perfluorobutyrimidoyl)perfluorobutyramidine. Essentially only one triazine (4) was formed, and it had the expected C_3F_7 groups in the 2 and 4 positions and the C_2F_5 group in the 6 position, although the total yield was about 50%.



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Subsequent acylations and dehydrations using both fluorinated and nonfluorinated carboxylic acid anhydrides gave yields in excess of 90%.

This method furnishes a route to synthesis of 1,3,5-triazines with any desired perfluoroalkyl groups in the 2, 4, and 6 positions. Its general applicability has been shown by the acylation and dehydration of N′-(perfluoroacyl)perfluoroalkylamidines with acetic anhydride to give 1,3,5-triazines with perfluoroalkyl groups in the 2 and 4 positions and a methyl group in the 6 position; further extension has been made also to give 1,3,5-triazines with chlorofluoroalkyl substituents.

Experimental Section[5]

Reaction of Perfluoropropionitrile with N′-(perfluorobutyrimidoyl)perfluorobutyramidine.—N′-(Perfluorobutyrimidoyl)perfluorobutyramidine (4.83 g, 0.012 mole) and perfluoropropionitrile (1.78 g, 0.012 mole) were sealed in a previously evacuated 30-ml glass ampoule and heated for 2 hr at 130°. Tests on a portion of the reaction mixture with dioxane (solid complex formation) indicated the presence of perfluoroalkyl-substituted triazine and with copper acetate (colored chelate formation) indicated only a trace remaining of the starting imidoylamidine. The product was heated to reflux for 24 hr under a nitrogen sweep to remove ammonia. Glpc analysis showed the following 1,3,5-triazines: 2,4,6-tris-C_2F_5, 2%; 2,4-bis-C_2F_5-6-C_3F_7, 21%; 2-C_2F_5-4,6-bis-C_3F_7, 45%; 2,4,6-tris-C_3F_7, 32%.

Previous preparations under similar conditions employing imiodylamidines and nitriles with the same perfluoroalkyl substituents gave essentially quantitative yields of 2,4,6-tris(perfluoroalkyl)-1,3,5-triazines.

2,4-Bis(perfluoropropyl)-6-perfluoroethyl-1,3,5-triazine.—N′-(Perfluorobutyrimidoyl)perfluorobutyramidine[3] (12.17 g, 0.0299 mole) was placed in a 100-ml, heavy-wall glass ampoule. The ampoule was cooled in liquid nitrogen and pumped free of air and 13.58 g (0.0746 mole) of perfluoropropionyl chloride was added. The ampoule was sealed, heated at 70° for 15 hr, and opened, and the crude liquid product (16.49 g) was filtered to remove a small amount of white solid. The filtrate was added to 1,4-dioxane to form 13.15 g of solid, white triazine–dioxane complex which was separated and treated with 5% aqueous hydrochloric acid. Crude perfluoroalkyl-substituted triazine (8.54 g) separated as a lower layer. Glpc analysis of this product showed it to be a mixture of 96% 2,4-bis(perfluoropropyl)-6-perfluoroethyl-1,3,5-triazine and 4% 2,4,6-tris(perfluoropropyl)-1,3,5-triazine. Yield of the major product was 51%. Fractional distillation gave chromatographically pure 2,4-bis(perfluoropropyl)-6-perfluoroethyl-1,3,5-triazine: bp 151–152°, $n^{25}\mathrm{D}$ 1.3101, d^{25} 1.6949.

Anal. Calcd for $C_{11}F_{19}N_3$: C, 24.67; F, 67.47; N, 7.58. Found: C, 24.89; F, 67.20; N, 7.91.

Synthesis of 2,4-bis(perfluoropropyl)-6-perfluoroethyl-1,3,5-triazine was carried out also by treating 5.0 g (0.012 mole) of N′-(perfluorobutyrimidoyl)perfluorobutyramidine with 15 g (0.048 mole) of perfluoropropionic anhydride. The anhydride was added slowly, resulting in the initial formation of a white solid with considerable evolution of heat; further addition gave a clear solution which was washed with water. Separation of the lower layer yielded 5.96 g (91%) of 2,4-bis(perfluoropropyl)-6-perfluoroethyl-1,3,5-triazine.

2,4-Bis(perfluoropropyl)-6-perfluoroheptyl-1,3,5-triazine.—N′-(Perfluorocaprylimidoyl)perfluorobutyramidine was prepared by adding to 10.24 g (0.0483 mole) of perfluorobutyramidine in 75 ml of methylene chloride a solution of 19.14 g of perfluorocaprylonitrile (0.0484 mole) in 15 ml of methylene chloride. The nitrile solution was added slowly over a period of 1 hr, stirring was allowed to continue at room temperature for 17 hr, and then the mixture was refluxed for 3 hr. Solvent was removed from the reaction mixture at room temperature under reduced pressure to leave 28.84 g of liquid, slightly viscous, N′-(perfluorocaprylimidoyl)perfluorobutyramidine.

Triazine was prepared by adding to 28.80 g (0.0475 mole) of N′-(perfluorocaprylimidioyl)perfluorobutyramidine and 42.01 g (0.1025 mole) of perfluorobutyric anhydride. White solids were formed in the initial exothermic reaction, but as the remainder of the anhydride was added the solids went into solution and a clear reaction mixture resulted. After addition of the anhydride was complete, the reaction mixture was stirred at room temperature for 20 hr and at 55° for 24 hr, then fractionated to yield 2,4-bis(perfluoropropyl)-6-perfluoroheptyl-1,3,5-triazine as a colorless, slightly viscous liquid: bp 216–217°, d^{27} 1.5179, $n^{27}\mathrm{D}$ 1.3133; the yield was 28.69 g (80%).

Anal. Calcd for $C_{16}F_{29}N_3$: C, 24.46; F, 70.19; N, 5.35. Found: C, 24.50; F, 70.32; N, 5.59.

2,4-Bis(perfluoropropyl)-6-trifluoromethyl-1,3,5-triazine.—N′-(Perfluorobutyrimidoyl)perfluorobutyramidine (46.91 g, 0.115 mole) was allowed to react with 107 g (0.51 mole) of trifluoroacetic anhydride by slow addition of the anhydride. The reaction mixture was stirred at room temperature for 3 hr then refluxed for 22 hr. Excess trifluoroacetic anhydride and trifluoroacetic acid were removed by distillation and the crude triazine was fractionated to yield 44.0 g (80%) of colorless liquid, 2,4-bis(perfluoropropyl)-6-trifluoromethyl-1,3,5-triazine: bp 144.5–145.0°, d^{25} 1.6842, $n^{25}\mathrm{D}$ 1.3113.

2,4-Bis(perfluoropropyl)-6-difluorochloromethyl-1,3,5-triazine.—N′-(Difluorochloroacetimidoyl)perfluorobutyramidine was prepared by placing 26.91 g (0.127 mole) of perfluorobutyramidine in a heavy-wall glass ampoule, and adding an equimolar amount of difluorochloroacetonitrile through the vacuum system. The reaction mixture was maintained at −80° overnight then at room temperature for 1 day. The reaction product was fractionated under reduced pressure to give a quantitative yield of N′-(di-

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[4] Dr. R. D. Spencer of the Mellon Institute, in a private communication, pointed out that the percentage distribution observed agreed closely with those which could be calculated for the random reorganization of two different groups, present in a 2:1 ratio, among three possible sites, *i.e.*, 3.7, 22.2, 44.4, and 29.6%.

[5] Microanalyses were by Schwarzkopf Microanalytical Laboratory, Woodside, N. Y.

fluorochloroacetimidoyl)perfluorobutyramidine: bp 72° (4.6 mm), d^{26} 1.6259, $n^{26}\text{D}$ 1.3763.

Triazine was prepared by adding 38.87 g of N'-(difluorochloroacetimidoyl)perfluorobutyramidine (0.12 mole) to 133.2 g of perfluorobutyric anhydride (0.325 mole). The reaction mixture was heated with stirring at 40–50° for 77 hr, then washed with water, distilled twice, and finally fractionated to give 41.7 g (70%) of 2,4-bis(perfluoropropyl)-6-difluorochloromethyl-1,3,5-triazine as a colorless liquid: bp 158–159°, d^{26} 1.6788, $n^{26}\text{D}$ 1.3303.

Anal. Calcd for $C_{10}ClF_{16}N_3$: C, 23.93; Cl, 7.08; F, 60.62; N, 8.37. Found: C, 24.23; Cl, 7.32; F, 60.49; N, 8.68.

2,4-Bis(perfluoropropyl-6-methyl-1,3,5-triazine.—Freshly distilled acetic anhydride (25 ml) was placed in a flask protected from atmospheric moisture and N'-(perfluorobutyrimidoyl)perfluorobutyramidine (22.23 g, 0.0546 mole) was added slowly over a 45-min period. The reaction mixture was stirred and refluxed for 21 hr, then washed with water to separate the crude triazine. Fractionation gave pure 2,4-bis(perfluoropropyl)-6-methyl-1,3,5-triazine: bp 162–163°, d^{26} 1.6079, $n^{27}\text{D}$ 1.3339.

Anal. Calcd for $C_{10}H_3F_{14}N_3$: C, 27.84; H, 0.69; F, 61.72; N, 9.74. Found: C, 28.03; H, 0.80; F, 61.57; N, 9.84.

2,4-Bis(perfluoroethyl)-6-methyl-1,3,5-triazine.—The preparation of 2,4-bis(perfluoroethyl)-6-methyl-1,3,5-triazine was carried out in the manner described for the previous preparation by treating 10.0 g of N'-(perfluoropropionimidoyl)perfluoropropionamidine with 20 g of acetic anhydride at reflux temperature for 5 hr. This reaction mixture was washed with water to yield 8.8 g of crude triazine. Fractionation through an 18-in. spinning-band column yielded pure 2,4-bis(perfluoroethyl)-6-methyl-1,3,5-triazine: bp 137–138°, d^{22} 1.5337, $n^{23}\text{D}$ 1.3427.

Anal. Calcd for $C_8H_3F_{10}N_3$: C, 29.00; H, 0.91; F, 57.40; N, 12.69. Found: C, 29.29; H, 0.87; F, 57.60; N, 13.01.

Fluorinated Acylthiophenes. Preparation of 5,5'-Diheptafluorobutyryl-2,2'-bithiophene *via* a Grignard Coupling Reaction

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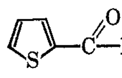
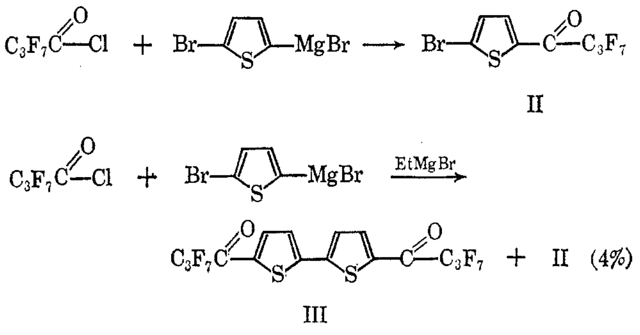
In general, 2,2'-bithiophenes (dithienyls) are prepared by the coupling of halothiophenes with metals[1-3] or less often by the coupling of Grignard reagents in the presence of a cohalide catalyzed by means of cobaltous chloride,[4,5] cupric chloride,[6] or oxygen.[7,8] (The uncatalyzed Grignard coupling reaction has been sparsely reported in the literature except in the case of benzyl halides.[9-11]) Few examples of the preparation of bithiophenes by the Grignard method have been effected without either a metal halide or treatment with oxygen.[12] Minnis isolated 5,5'-di(triphenylmethyl)-2,2'-bithiophene in an attempt to prepare triphenylthienylmethane from triphenylchloromethane and thienylmagnesium iodide.[13] Others[14] have reported the isolation of 5,5'-dichloro-2,2'-bithiophene in 5% yield during the preparation of 5-chloro-2-vinylthiophene from 5-chloro-2-thienylmagnesium bromide and acetaldehyde. Attempts in this laboratory to prepare 2,5-diheptafluorobutyrylthiophene (I) from the Grignard compound of 2,5-dibromothiophene also gave, in the presence of ethyl bromide alone, a coupled product, 5,5'-diheptafluorobutyryl-2,2'-bithiophene (III, discussed below).

We have previously shown that many synthetic approaches used for the acylation of thiophene and substituted thiophenes cannot be utilized for the preparation of a fluorinated acylthiophene.[15] The desired product (IVa) was prepared, however, by the addition of 2-thienylmagnesium bromide to the acid chloride. This work has now been extended to the preparation of other fluorinated acylthiophenes by the same Grignard technique. The use of the intermediates pentafluoropropionyl chloride and pentadecafluorocaprylyl chloride gave the expected compounds IVb and IVc.



IVa, R = C_3F_7
b, R = C_2F_5
c, R = C_7F_{15}

An attempt to prepare I, under reaction conditions similar to the preparations of IVa–c, gave, instead, 2-heptafluorobutyryl-5-bromothiophene (II). To facilitate the formation of Grignard in the 5 position of 2,5-dibromothiophene, the entrainment method for inactive halides was attempted using ethyl bromide as the cohalide.[16,17] As in the previous case, the expected product (I) could not be isolated. The main product obtained was the bithiophene (III) in 26% yield. The reaction also gave a 4% yield of II.



In the reactions for the preparations of II and III, the metal impurities contained in the commercial magnesium turnings[18] apparently do not significantly promote the Wurtz reaction. This is indicated by the failure to isolate the coupled products III or 5,5'-dibromo-2,2'-bithiophene from the reaction for the

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[11] M. S. Kharasch and W. H. Urry, *J. Org. Chem.*, **13**, 101 (1948).

[12] It has been reported that small amounts of metal impurities in ordinary commercial magnesium turnings promote the Wurtz reaction and give coupled products. See (a) G. O. Johnson and H. Adkins, *J. Am. Chem. Soc.*, **53**, 1520 (1931); (b) *ibid.*, **54**, 1943 (1932); (c) M. S. Kharasch, S. C. Kleiger, J. A. Martin, and F. R. Mayo, *ibid.*, **63**, 2305 (1941); (d) ref 5.

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[16] M. S. Kharasch and O. Reinmuth, "Grignard Reactions of Nonmetallic Substances," Prentice-Hall Co., Inc., New York, N. Y., 1954, pp 38–45.

[17] D. E. Pearson, D. Cowan, and J. D. Beckler, *J. Org. Chem.*, **24**, 504 (1959).

[18] Per cent metal impurities: Al, 0.001; Cu, 0.004; Mn, 0.1; Ni, 0.02; Fe, 0.02.